The Virtual Naval Hospital: the digital library as knowledge management tool for nomadic patrons*

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Objective: To meet the information needs of isolated primary care providers and their patients in the US Navy, a digital health sciences library, the Virtual Naval Hospital, was created through a unique partnership between academia and government.

Methods: The creation of the digital library was heavily influenced by the principles of user-centered design and made allowances for the nomadic nature of the digital library's patrons and the heterogeneous access they have to Internet bandwidth.

Results: The result is a digital library that has been in operation since 1997, continues to expand in size, is heavily used, and is highly regarded by its patrons.

Conclusions: The digital library is dedicated to delivering the right information at the right time to the right person so the right decision can be made, and therefore the Virtual Naval Hospital functions as a knowledge-management system for the US Navy Bureau of Medicine and Surgery.

INTRODUCTION

The mission of the US Navy, which includes the US Marine Corps, is to maintain, train, and equip combat-ready naval forces capable of winning wars, deterring aggression, and maintaining freedom of the seas. The mission of the US Navy Medical Department is to support the combat readiness of the uniformed services and to promote, protect, and maintain the health of all those entrusted to their care, anytime, anywhere.

Navy Medicine can be considered a virtual academic medical center, with approximately 37,000 US Navy medical professionals working in hundreds of medical campuses and departments around the world, all operating under a single administrative structure. Like any academic medical center, Navy Medicine contains a large amount of knowledge [1]. This knowledge has traditionally been codified in the form of lessons learned and best practices in print textbooks. Unfortunately, Navy Medicine's mission is complicated by the fact that naval primary care providers are among the most geographically isolated health care providers in the world and rarely have convenient access to the authoritative operational naval medical information that they need to deliver optimal patient care.

The US Navy has a long history of using knowledge-management systems, taking the first such commercially available system to sea in 1983 [2]. Recently, the US Navy has defined knowledge management as the ''delivery of the right information at the right time to the right person so the right decision can be made'' and has dedicated itself to deploying knowledge-management tools to its personnel [3].

In 1996, Navy Medicine desired to digitize its knowledge and create a knowledge-management tool, using digital library technology, to provide primary care providers and patients convenient access to authoritative operational naval medical information at the point of care. The Navy approached digital library researchers at The University of Iowa, who, since 1992, had a history of providing digital library services to isolated rural primary care providers and their patients through the Virtual Hospital digital library [4]. The Navy wished to leverage The University of Iowa's expertise to deliver digital library services to isolated naval primary care providers and patients at sea and in the field.

Thus, the Virtual Naval Hospital™ <http://www.vnh.org> was commissioned in 1997, with a mission of creating and curating a digital health sciences library to make the Internet a useful medical reference tool for naval primary care providers at the point of care, by helping them take better care of patients, and, as a health promotion tool for sailors and marines, to help personnel live healthier lives.

The Navy and Marine Corps are nomadic, spending much of their time at sea or in the field away from their bases, which adds to the complexity of the project. During these times, they have heterogeneous access to Internet bandwidth, ranging from no access (much of the time), to low-speed access, to high-speed access in exceptional circumstances. The great challenge of this digital library project therefore is to deliver digital library services to a nomadic patron population on the sea, under the sea, in the air, and in the field. The purpose of this paper is to share a number of valuable lessons that have been learned about delivering digital library and knowledge-management services to nomadic patrons.

APPROACH TO DIGITAL LIBRARY DEVELOPMENT

A five-step approach was used to develop this digital library.

1. Envision and strategize

The first step was performing a formal needs assessment to determine the information needs of naval primary care providers and patients at sea. This formal needs assessment comprised two parts: a literature-based needs assessment and an interview-based needs assessment. The literature-based needs assessment reviewed eighty-one articles in the naval medical literature and identified the most common medical problems encountered at sea, along with the most important health promotion topics applicable to sailors and marines. An interview-based needs assessment with twelve naval primary care providers was then undertaken as a ''reality check'' and corroborated the findings obtained from the literature [5].

Content for the digital library was obtained by identifying US Navy and US government medical textbooks that covered the previously defined common medical problems and important health promotion topics. These textbooks—which are written in English, peer reviewed, and regularly updated—contain knowledge encompassing over 200 years worth of institutional experience with operational naval medicine codified in the form of lessons learned and best practices. Because of the US Navy's worldwide commitments and operations, the Virtual Naval Hospital's core content, covered in these textbooks, includes the most common primary care problems in the developed and the developing world. This content is supplemented by content covering preventive medicine and medical problems that, until most recently, were faced solely by the military, such as biological, chemical, and nuclear warfare. US Navy medical administrative manuals are also included in the Virtual Naval Hospital. The Virtual Naval Hospital Website content is updated and expanded regularly. With this content at its core, the digital library therefore functions as a knowledge-management tool for Navy Medicine.

All textbooks, in paper or electronic format, were converted into hypertext markup language (HTML) files. Additional content was obtained by identifying medical textbooks on authoritative non-US government medical Websites that could be linked to.

2. Design

The information architecture of the digital library is designed according to the principles of user-centered and learner-centered design [6, 7]. The patron's daily information needs, defined above, were organized into a problem-based integrated interface to the digital library's content that allows the patron, whether primary care provider <http://www.vnh.org/Providers.html> or patient <http://www.vnh.org/Patients.html>, to

quickly and easily answer common questions and solve common problems that they face in daily work.

3. Deploy

The data architecture and software architecture of the digital library is built on open Internet standards that allow for scalability, interoperability, and modifiability as the information in the digital library is expanded and new computer and communications hardware and software technologies become available. All documents are stored as HTML files and adhere to a uniform style that minimizes the use of graphics to ensure that navigation in the digital library is clear and quick [8] and that patrons can have confidence in the information they are reading [9]. Images are stored as graphic interchange format (GIF) and joint photographic experts group (JPEG) files. Browser plug-ins and helper applications are not required. The repository for all these documents is a Web server (Apache Software Foundation, Forest Hill, MD), where they are indexed and made free-text searchable by a relevance-based search engine (ht://Dig Group, San Diego, CA), with the entire system running on a Linux-based operating system (RedHat, Raleigh, NC).

To allow access to the digital library when the patron does not have continuous Internet access, a caching strategy has been developed that would be technologically durable, readily understandable, and easily implemented by patrons who have been assumed to have limited computer skills and no access to technical support. A CD-ROM mirror of the digital library, which can be used as a locally cached version of the digital library on nomadic patrons' personal computers, is produced biennially and distributed to approximately 10,000 US Navy medical professionals who do not have consistent Internet access while serving at sea or in the field.

In September 2003, the digital library contained 400 megabytes of content comprising 60 medical textbooks and more than 1,500 links to authoritative medical textbooks on nongovernmental Websites <http://www.vnh.org/Misc/SiteMap.html>. The digital library and its CD-ROM mirrors are currently deployed on every ship, submarine, aviation squadron, medical clinic, hospital, and Marine battalion in the US Navy. The digital library's daily operation is the responsibility of the University of Iowa with oversight from the US Navy.

4. Operate and sustain

The successful day-to-day operation of this digital library is due to a unique partnership between academia and government. The principals in this project, who have formed a close collaborative relationship, each have strong multidisciplinary backgrounds that collectively cover operational naval medicine, primary care medicine, medical informatics, basic sciences research, government and university administration, and naval history. Working together, this team has been able to positively address a number of social, political,

economic, and technical challenges. Although begun as an operational prototype, the digital library's success at filling a previously unidentified, and therefore unmet, need for authoritative medical information at the point of care, along with its cost effectiveness, have allowed it to become a sustainable project for Navy Medicine [10].

5. Assess, validate, and re-strategize

Ongoing evaluation of the digital library is a key part of a process of continuous quality improvement. Web server log file records are analyzed using Analog (Stephen Turner, Santa Cruz, CA) and Wusage (Boutell.com, Philadelphia, PA) and show overall usage of the digital library has grown at a steady rate since being commissioned <http://www.vnh.org/Misc/Statistics.html>. In September 2003, the digital library Website was used by approximately 125,000 patrons, who read approximately 750,000 pages of information, with a broad spectrum of information accessed. Approximately 66% of this usage is from US Navy medical professionals. The CD-ROM mirrors most likely receive even more usage, which cannot be tracked.

Patron feedback is encouraged and obtained via an online comment form <http://www.vnh.org/refer/Misc/Comment.html> with an average of twenty comments received per month. These comments contain a mixture of questions, corrections, suggestions for content additions, and praise for the digital library. Over time, the digital library has been revised, expanded, and enhanced based on this feedback as well as formal evaluations.

The praise from feedback forms <http://www.vnh.org/Misc/FanMail.html>—as well as independent reviews <http://www.vnh.org/Misc/Reviews.html> and combat experience during recent conflicts in the Balkans, Southwest Asia, and the Middle East—shows overall satisfaction with the digital library and demonstrates that the user-centered approach to the digital library's development has placed it squarely ''in the ballpark'' of meeting patrons' information needs.

DIGITAL LIBRARY LESSONS LEARNED

Following these lessons when developing a new digital library to serve as a knowledge-management tool should help increase its chance of success.

1. Begin with a formal needs assessment

By listening to and observing patrons and defining their information needs, the formal needs assessment provides the foundation on which the digital library is built. Digital library projects that ignore their patrons' information needs from the start do so at their own peril and place themselves at high risk for failure.

2. Incorporate principles of user-centered design in the information architecture

Designing the digital library's information architecture around the results of the formal needs assessment is

crucial to making the digital library relevant to the patrons' needs. Such a user-centric digital library gives patrons a compelling reason for its use and has greater potential to be easily integrated into their work flow and thus be used. The ultimate goal should be to change patrons' usage paradigm of the Internet from one of Web surfing to one of problem solving.

3. Use lowest common denominator Web technology and design in the data architecture: less is more

The special needs of nomadic patrons has to be respected and accommodated during the design process as the majority of the patrons have heterogeneous access to Internet bandwidth from a wide spectrum of computing platforms. Using the minimum level of technology needed to support the patrons in accomplishing their mission has resulted in a technologically simple digital library data architecture, with lowest common denominator Web technology and design standards. This simple solution, however, is the digital library's true power, for it allows the digital library to be cross platform and machine independent.

The standard today is for knowledge-management systems to be implemented using proprietary commercial software tools that are powerful but also expensive and complex to install, administrate, and integrate with other vendor's software tools [11]. The net result is that once an institution implements a knowledge-management system using such a closed solution, they are often practically locked into that solution for a long time regardless of how well it functions.

Our knowledge-management system is unique in that it is implemented using open source software tools that are powerful but free and straightforward to install, administrate, and integrate with other open source software tools. The net result is that once the institution implemented this knowledge-management system using an open solution, it remained free to continue to add functionality as new open source software tools become available.

This frugal approach to knowledge management has allowed the team to build a highly effective open source, knowledge-management system that has most of the functionality of its proprietary commercial counterparts and will continue to add functionality over time as more open source software tools become available.

4. Remember people, not technology, make the project work

A digital library project requires key intermediaries, individuals with multidisciplinary backgrounds, who can interact with the different constituencies involved in a digital library project and who translate and negotiate between constituencies to overcome obstacles and keep the project on course and moving forward.

5. Listen to and act on patron feedback

Feedback from patrons, obtained from online comment forms and face-to-face meetings, is a gold mine of information of how the digital library serves, or fails to serve, its patrons. More often than not, the patrons' suggestions, once implemented, help significantly improve the digital library's service.

DISCUSSION

An institution such as the US Navy is defined by its bases, its equipment, its personnel, and the knowledge they possess. While the Navy must invest in maintaining bases and equipment and preserving their capabilities, it must also invest in maintaining its personnel and preserving their knowledge. Clearly, one way to do this is through creating knowledge-management tools using digital library technology. By helping primary care providers take better care of their patients and helping sailors and marines live healthier lives, the Virtual Naval Hospital helps to ensure that naval personnel are able to answer the call to duty when needed, thereby maximizing military readiness.

A number of valuable lessons have been learned about delivering digital library and knowledge-management services to nomadic patrons: to succeed in the design and implementation of a digital library that serves as a knowledge-management tool, regardless of the field of endeavor, one must focus initially and then consistently on the population served and their mission and tailor the digital library to their needs. When this focus is kept, the result will be a knowledge-management tool that is heavily used and sincerely appreciated.

CONCLUSION

In the future, as society moves toward a ubiquitous computing environment to accommodate an increasingly nomadic lifestyle [12], access to digital libraries will be primarily by mobile workstations or wearable computers with lower-speed wireless connections to the Internet. Therefore, one of the next grand challenges of future digital library research will be to determine how to deliver effective digital library services to nomadic patrons. The lessons learned from this project take a first step in showing the way.

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